The Control of the Destructive Spruce Bark Beetle in Eastern Canada

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DOMINION OF CANADA
DEPARTMENT OF AGRICULTURE

PAMPHLET No. 48—NEW SERIES

THE ENTOMOLOGICAL BRANCH
ARTHUR GIBSON, Dominion Entomologist

Printed by direction of the Hon. W. R. MOTHERWELL, Minister of Agriculture, Ottawa, December, 1924

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1925

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INTRODUCTION

The Destructive Spruce Bark-beetle* is the most dangerous and destructive insect enemy of mature spruce throughout the coniferous forests of Canada** and several important recent outbreaks by the species have brought it to the attention of timber owners, foresters and entomologists.

These outbreaks can be controlled by modified logging operations, usually without great expense if the control work is undertaken in time, and this account is presented to urge those in charge of mature spruce timber to watch constantly for the initial stages of the injury, and to adopt the control measures recommended herein whenever sufficient stands of timber require to be protected.

Reports of severe injury to mature spruce forests in various parts of eastern North America have appeared from time to time, the oldest authentic record of the kind dating back to the beginning of the last century. Many of these outbreaks undoubtedly were caused by the spruce budworm, but others refer clearly to the work of bark-boring beetles of the family Ipidae, principally the Destructive Spruce Bark-beetle, *Dendroctonus piceaperda* Hopk. The older outbreaks are described by Packard and Hopkins and in publications of the Entomological Branch.

The last recorded outbreak by this beetle, and the first to be studied carefully, occurred throughout a large part of Maine and New Brunswick and in south-eastern Quebec during the years 1897 to 1901. The injury was studied by Dr. A. D. Hopkins and the very excellent account of the whole situation published by him in 1900 has been our authority on this subject until the present time. It should be emphasized that during that outbreak more than a billion feet of the finest spruce were estimated to have been killed in Maine and New Brunswick before the injury ceased.

During the decade previous to 1915, this beetle appeared to be exceedingly rare in eastern Canada. Since that time extensive outbreaks have developed and spread in the Gaspe peninsula, Que., and in the Algoma District, Ontario, and it has become generally common in many spruce stands in New Brunswick and as far west as Lake Superior.

Very recently we have been advised of a quantity of dying spruce in Newfoundland and sections of infested logs submitted to us were filled with the tunnels and adults of *Dendroctonus piceaperda* Hopk.

During the last five years somewhat extensive outbreaks of this spruce beetle have occurred in northern Manitoba and northern Saskatchewan and are known to be still active there in some localities. During the last ten years the writer has met with numerous large or small outbreaks in various parts of British Columbia and northern Alberta caused by this species or its western representative *Dendroctonus borealis* Hopk. Throughout these western regions, where windfalls and snowbreaks are frequent, this species is generally abundant and needs only slight encouragement to become epidemic.

**Dendroctonus piceaperda* Hopk. in eastern Canada, *Dendroctonus borealis* Hopk. in British Columbia.
**Excepting only the Spruce Budworm on red spruce of New Brunswick.

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The history of dying spruce in the Gaspe peninsula was observed and reported to the writer by Mr. A. D. Patterson.

In 1896, on the Dartmouth river, nearly all the largest spruce trees were fallen. Since only the largest trees were killed, this possibly indicates a bark-beetle outbreak in the previous ten years. In 1899 and 1900, dying spruce was noticed on the south side of the York river; about twenty large dead spruce were counted on one small area. During the following years, until 1915, large dying spruce were noticed, scattered throughout the area, but no particular attention was paid to them. The dying trees increased rapidly subsequent to 1916. In 1916 about 6 scattered dead spruce were noticed on Block 54; at the same place, in 1918, 25 dead trees were counted, and over all the country one could find dead spruce in small groups of 4 to 6. In 1919 and 1920 the number of dead trees increased very rapidly. The greatest number of dead trees was found, at first, in the eastern part of the area along the lower portion of the York and St. John rivers and was most noticeable on the higher land, where the windfall mentioned in the following paragraph was heavier. Later, the infestation spread up the St John as far as the belt of black spruce and thence back north-east across the upper reaches of the York and Dartmouth rivers. In 1921 the injury decreased on the lower St. John river and increased along the upper part of both the St. John and York rivers.

On June 5, 1915, a very heavy snowstorm, accompanied by a high wind, occurred throughout a large part of the Gaspe peninsula. Large trees were broken or blown down individually or in groups and an immense quantity of timber was destroyed. Eighteen inches of snow was reported for the high lands of the interior.

On October 29, 1918, an exceedingly heavy wind storm swept the same area, exhibiting its greatest severity toward the south. It was reported that in many places acres of trees were blown down and a heavy windfall occurred throughout the whole southern half of the peninsula.

In Mr. Patterson's account, just given, the dead trees first began to increase rapidly in 1917 and 1918, and the increase continued to be rapid through 1919 and 1920. This species breeds abundantly in wind-thrown trees and it seems probable that these two windfalls were responsible for the rapid development of the outbreak. Consequently, if it had been feasible to log out the greater part of the windfalls during the first winter, particularly in the neighbourhood of stands of large spruce, the subsequent loss from beetle injury might have been avoided entirely.

The writer wishes to acknowledge his indebtedness to the officers of this Division and to the foresters of the Dominion Forestry Branch who have assisted in the field work relating to this problem. Dr. F. C. Craighead accompanied the writer on a preliminary inspection of the Gaspe infestation in the summer of 1921. Mr. M. B. Dunn has taken an important part in the field work in eastern Quebec and New Brunswick. Mr. H. S. Fleming has given general assistance with the field work in the Gaspe peninsula. Mr. C. R. Christie of the Dominion Forest Branch made a special examination and report on infestations in the Porcupine Reserve, Sask. Mr. C. MacFayden, of the Dominion Forest Branch, accompanied the writer in an extensive survey of bark beetle conditions through parts of northern Saskatchewan and northern Manitoba.

Our grateful acknowledgment is due the officers of the Howard Smith Paper Mills Limited for their invaluable assistance in facilitating our investigation in the Gaspe peninsula; we are particularly indebted to Mr. L. J. McKenzie and to Mr. A. D. Patterson, also, for their reports on conditions in earlier years and on areas which we were unable to visit. Mr. Patterson accompanied us on many of our field trips and made special examinations and reports on different areas at our request. The control work conducted by this company in the winter of 1922-23 is the only example of actual control yet attempted for this injury in eastern Canada.

General Appearance of an Outbreak

The general appearance of a beetle-infested forest is quite characteristic. The largest spruce, 10", d.b.h. and larger, turn red in clumps and scattered patches. The infested trees usually die in one year, losing their foliage by the first winter following the attack, and the injury spreads in the subsequent summer to the surrounding green timber. Almost invariably the infested green trees show many small masses of gum, about the size of the thumb or smaller, described later as "pitch-tubes", thickly studded over the lower 10 to 40 feet of the bark of the trunk. Many beetle-infested trees have the bark partly removed by woodpeckers, which feed upon the developing broods and are often an important factor in checking or preventing outbreaks. Whenever the larger mature spruce is found to be dying in considerable numbers and exhibits the characters just described, the work of the Destructive Spruce Bark-beetle is to be suspected; and, if valuable stands of timber appear to be threatened, a careful inquiry, under the direction of a competent forest entomologist, should be undertaken.

General Habits and Method of Attack

The adult beetles are cylindric in shape, about one-quarter of an inch in length, with a hard integument; they are dark red or black in colour. They fly readily and spread the infestation from trees they have killed or from stumps, windfalls and culled logs to living trees in the neighbourhood. Their young are whitish, legless grubs, one-quarter of an inch long when full grown, found between the bark and the wood, usually on the lower half of the trunk of infested trees.

The adult beetles emerge from the infested bark during the summer and enter the uninjured bark of dying or living trees. They never attack dead trees. Each pair of beetles bores a round entrance tunnel through the bark to the wood surface and then continues the entrance tunnel as an egg-tunnel up the trunk between the bark and wood, but mainly in the inner bark, for about six inches. The female deposits numerous eggs along the sides of this egg-tunnel and the grubs which hatch from the eggs excavate individual mines in the inner bark, and later between the bark and wood, more or less at right angles to the main egg-tunnel. The grubs or larvae become mature towards the end of the season and either pass the winter under the bark as grubs or transform to adult beetles before winter, remaining beneath the bark until the following summer. During June, July and August, the beetles all emerge from the bark of the trees in which they have bred and attack fresh standing trees, windfalls, stumps or logs in the neighbourhood.

When green, standing trees are attacked, a mass of gum, called a "pitch-tube", is almost invariably formed around each entrance hole, and these pitch-tubes, studded over the bark of the trunk, distinguish the infested trees, known as "beetle-trees", even before the foliage has changed in colour. When tunnels are cut in the bark of dying trees, and windfalls or logs in which the resin will no longer flow, no pitch-tubes are formed and the work of the beetles is betrayed only by the reddish boring dust lodged in the bark crevices below the tunnel openings. During the latter part of the summer the foliage of the beetle-trees infested during June and July turns yellowish in colour and falls in large part before winter. The trees attacked during August may retain a considerable part of their foliage until spring, but the paler or yellowish colour serves to distinguish them from healthy trees..

This species breeds freely in dying trees, such as windfalls, stumps, trees injured at the base by fire, and culled logs from cuttings; but when the beetles are numerous *they readily attack living, healthy spruce of the largest size.* They select the largest, mature trees, attacking them during summer, and by winter,

or the following spring at latest, the trees are dead and the needles nearly all fallen. The beetles emerge from the bark and leave the trees finally the following season. In the rare cases in which a tree is not killed in one season by a beetle attack in which the brood matures, it is usually found that a small brood has succeeded in maturing on one side at the base of the trunk. A top infestation in standing trees has not been noticed during our study.

Detailed Description

Adult beetle: length 4.5 mm. to 6.2 mm.; about 2.4 times as long as wide; black when mature, or with the elytra very dark reddish yellow to reddish brown when immature; the *front* impressed on the median line towards the vertex, the epistomal process wide with the sides oblique; the *pronotum* strongly constricted in front, slightly narrower than the elytra, the punctures deep, small and large intermixed; the caudal half of the proepisternal area granulate; the *elytral* disc clothed with long erect hairs, the punctures of the discal striae usually coarse, the striae often strongly impressed on the sides; the declivity convex.

The male has the declivity somewhat smooth and shining with the punctures indistinct.

The newly transformed beetles are pale yellow in colour, passing through yellowish-red to reddish-brown and finally to piceous or almost pure black. By October many of the earliest broods of the season are quite black or black with the elytra dark red. Hibernated old beetles are entirely black; the emerging broods, particularly those of the second brood, have many individuals reddish or black with red elytra.

The *eggs* are minute, white, arranged by the female in rows along the sides of the egg tunnel and packed in with boring dust.

The *larvae* are minute when hatched, feeding on the bark at first in congress, but later excavating individual mines in the inner bark radiating away from the egg-tunnel. They increase gradually to a length slightly greater than the adult beetle. They have the characteristic scolytid appearance and are distinguished by a chitinous plate on the dorsum of each of the last two abdominal segments.

Description of the Tunnels

The tunnels consist of an entrance tunnel, an egg-tunnel, ventilation tunnels, feeding galleries and larval mines. The entrance-tunnel is round in section, slightly greater in diameter than the adult beetle, about 3 mm., and extends obliquely upward from the entrance hole on the bark surface to the surface of the wood, where it extends into the egg-tunnel. The latter is usually straight, vertical, lying chiefly in the inner bark and scoring the wood only slightly. The length varies from four to about six or eight inches, and the width of the bore from 3mm. to 4 mm. The eggs are deposited in one, two or three egg-layers, arranged alternately along the sides of the tunnel, each layer containing between 40 and 50 eggs. A groove is cut for each layer from the side of the tunnel, the eggs deposited side by side, usually in a single or, less frequently, in a double row, the long axis towards the heart of the tree, and packed in with boring dust, so that each egg-layer is set into the tunnel wall; more or less boring dust is packed about the tunnel walls so that the bore of the tunnel is kept uniformly cylindric.

Short tunnels, called ventilation tunnels, from 3 or 4 to 9 or 10 in each egg-tunnel, are cut from the roof of the egg-tunnel outward into the outer layers of the bark, but, usually, are not extended quite to the surface. These are used as turning niches. They are frequently extended later as exit holes for the parent beetles, and may serve to a small degree in ventilating the tunnels.

The tunnels are kept free of boring dust and liquid resin by the beetles. The female sweeps the accumulated debris back towards the entrance-hole, from which it is ejected by the male. Not infrequently the latter is overcome by his labour, and is found dead in the entrance tunnel preserved in a mass of resin and frass. In such cases the female extends a ventilation tunnel to the surface, which serves as an entrance tunnel, and she is frequently joined by a second male.

From the upper end or from the sides of tunnels started in early summer, short food galleries are cut by the parent adults previous to their migration to fresh trees in mid-July.

The larval mines are excavated at first in the inner bark and later between the bark and wood, engraving the latter only at the outer ends, and radiating away from the egg-tunnel. They are always filled with excrement. For a short time after hatching, the larvae from each egg layer feed in congress and excavate a very thin chamber in the inner bark. At about half an inch from the egg tunnel the larvae begin to separate and thereafter cut individual mines which are kept separate and subparallel so long as space permits. As the larvae become mature they enlarge the end of the mine to form an oval, well-defined, smooth-walled pupal cell, usually engraving the wood surface, but sometimes situated in the middle bark; within this the pupal period is passed, preceded by a distinct prepupal stage.

In heavily infested trees the beetle tunnels may extend from the base well into the upper part of the crown, but more frequently only the lower two logs are attacked. The following description is typical of a heavily infested beetle tree attacked while green and making good growth: A red spruce 18", d.b.h., felled and studied, July 12, 1922. Heavily infested on lower 40 feet, slight growth that season previous to attack, new twigs 2 inches long. The tunnels were 3 inches to 4 inches long, with many eggs laid, but few larvae hatched; tunnels very closely placed; on an area of 8.5 square feet there were 69 tunnels including those with only part on that area, or about 8 tunnels per square foot. On the whole infested portion of the trunk there were 750 tunnels by actual count. The intensity of the attack was evidenced, also, by the number of eggs

being laid. The tunnels had already two or three egg-layers and in many of them the eggs were in two rows. Ten egg-layers counted contained eggs as follows: 56, 40, 41, 51, 46, 50, 50, 43, 52, 45, average 48. With an average of two layers per tunnel, a low estimate, there were more than 72,000 eggs already laid. Tunnels, then one half an inch long, were being started in the top of the tree by single black beetles, which had already completed one set of tunnels that season, apparently in a neighbouring tree. The majority of the tunnels would contain three egg-layers when completed, so that there would have been well over 100,000 eggs deposited in this tree before winter.

Seasonal History

The species hibernates in the tunnels as old black adults (in the egg-tunnels), parents of part of the last brood of the previous summer; young adults, variously coloured from reddish to black, progeny of the first tunnels cut early in the previous summer; and larvae in all stages from very small to nearly mature. While nearly all gradations may be found in different trees, the hibernating broods may be grouped roughly into those with the broods nearly mature, consisting of young adults with or without large larvae, and those with broods all in the younger larval stages. The former are from the tunnels cut early in the previous summer, the latter from the tunnels cut late in the previous summer during the month of August.

The old adults, which hibernate in August egg-tunnels, emerge during June and early July of the following season and cut new tunnels. It was certain that this emergence occurred in 1923 from many tunnels examined, although not from all, and that as a rule these old beetles finally died within the second tunnels. This emergence is apparently partial, owing to a heavy winter mortality, and is probably the earliest in the season. It should receive further study. It is possible that some of the old beetles may cut a third set of tunnels.

The progeny of these tunnels, the first broods of the season, hibernate as young adults with a few large larvae, and emerge from the old tunnels to attack new trees in late June and July, participating in the earliest attack of the following season. After the first egg-tunnels are completed the beetles abandon them, in the latter part of July and August and cut new egg-tunnels, in which they die after the eggs are deposited.

There was some evidence that a portion of the first brood matured and emerged from the trees and cut new tunnels late in the season of 1923.

All the broods which hibernate as young adults and mature larvae emerge and attack fresh trees during late June and early July.* For the last two years this has been the heaviest attack of the season. By the middle of July, in many of these tunnels, the complement of eggs is deposited, and the parent beetles, in many cases at least, cut short food tunnels, either at the inner end of the tunnel (♀) or from the side (♂) and later excavate new egg-tunnels, usually in the tops of trees already infested in the lower trunk. In the many cases examined these beetles were dead in the tunnels in the following spring.

The progeny from the second tunnels, cut in August, the second broods of the season, hibernate as larvae in all stages from small to nearly full grown; they reach maturity and emerge from the tunnels to attack new trees in late July and August of the following year. These beetles cut egg-tunnels in August, within which they hibernate, and they emerge and cut a second set of tunnels in the following June or early July and usually die therein.

The multiplicity of broods which results from this double brooded habit is illustrated in the following table, in which the progeny of the hibernated old adults, which have cut their first tunnels during the previous August, are indicated for a period of four years.

*In the Algoma District of Ontario the summer of 1924 was cold and backward, and in several cases broods of *piceaperda*, originated in 1923, remained in the bark throughout the summer of 1924 and will presumably emerge in the summer of 1925.

1919

Parent Beetles Date of Origin	1st or 2nd Tunnels	Date of Attack	History of Progeny	Designation of brood
Hibernated Old Beetles..... (Emerged July-August, 1918)	2nd Tunnels..... (Die in Tunnels)	June-July	Progeny hibernated as adults and emerged June-July, 1920.	A

1920

A Beetles Young adults..... June-July, (1919)	1st Tunnels.....	June-July	Progeny hibernated as young adults and emerged June-July, 1921.	a
	2nd Tunnels.....	July-Aug.	Progeny hibernated as larvae and emerged July-Aug., 1921.	b

1921

a Beetles Young adults..... (June-July, 1920)	1st tunnels.....	June-July	Progeny hibernated as young adults, emerged June-July, 1922.	c
	2nd tunnels.....	July-Aug.	Progeny hibernated as larvae, emerged July-Aug., 1922.	d
b Beetles Young adults..... (July-Aug., 1920)	1st tunnels.....	July-Aug.	Progeny hibernated as larvae, emerged July-Aug., 1922.	e
	.....	.....	Adults hibernated in 1st tunnels winter of 1921.	b b

1922

bb. Beetles, hibernated b beetles..... (July-Aug., 1920)	2nd tunnels.....	June-July	Progeny hibernated as young adults, emerged June-July, 1923.	j
c. Beetles Young adults..... (June-July, 1921)	1st tunnels.....	June-July	Progeny hibernated as young adults, emerged June-July, 1923.	f
	2nd tunnels.....	July-Aug.	Progeny hibernated as larvae, emerged July-Aug., 1923.	g
d. Beetles Young adults..... (July-Aug., 1921)	1st tunnels.....	July-Aug.	Progeny hibernated as larvae, emerged July-Aug., 19_3.	h
	.....	.....	Hibernated in 1st tunnels winter of 1922.	dd
e. Beetles Young adults..... (July-Aug., 1921)	1st tunnels.....	July-Aug.	Progeny hibernated as larvae, emerged July-Aug., 1923.	i
	.....	.....	Hibernated in 1st tunnels winter of 1922.	ee

1923

Parent Beetles Date of Origin	1st or 2nd Tunnels	Date of Attack	History of Progeny	Designation of brood
dd. Beetles, hibernated d Beetles, July-Aug., 1921	2nd tunnels	June-July	(Adults die in tunnels).	
ee. Beetles, hibernated e Beetles, July-Aug., 1921	2nd tunnels	June-July	(Adults die in tunnels).	
f. Beetles (June-July, 1922)	1st tunnels	June-July	(Progeny emerge June-July, 1924.)	
	2nd tunnels	July-Aug.	(Progeny emerge July-Aug., 1924.)	
j. Beetles (June-July, 1922)	1st tunnels	June-July	(Progeny emerge June-July, 1924.)	
	2nd tunnels	July-Aug.	(Progeny emerge July-Aug., 1924.)	
g. Beetles (July-Aug., 1922)	1st tunnels	July-Aug.	(Hibernate in 1st tunnels winter of 1923).	
h. Beetles (July-Aug., 1922)	1st tunnels	July-Aug.	(Hibernate in 1st tunnels winter of 1923).	
i. Beetles (July-Aug., 1922)	1st tunnels	July-Aug.	(Hibernate in 1st tunnels winter of 1923).	

Thus from a single brood of young adults, A., emerging in June, 1920, there would be, in the summer of 1923, nine broods taking part in the season's beetle attack and three of the same broods hibernating to take part in the early season's attack in 1924.

The habit of these beetles in cutting two sets of tunnels in separate trees is largely responsible for the almost continuous attack from June to September and it also very greatly extends the food supply available to the larvae. The time intervening between the deposition of the eggs of the first and second tunnels provides for the first and second seasonal emergence and attack that have been evident in eastern Canada during the last two summers. The heaviest emergence of adults and attack on fresh trees takes place late in June and early in July, and a second, apparently somewhat lighter, emergence and attack occurs from the last week of July through the first half of August. The multiplicity of broods taking part in an infestation and the differing conditions of hibernation, with the resulting variability in time of emergence, results in an almost continuous attack throughout the season; but the two periods of maximum emergence are quite evident.

Secondary Species

The *Dendroctonus* attack on green trees is usually followed closely by swarms of the four-eyed Spruce Bark-beetle, *Polygraphus rufipennis* Ky., the Lesser Northern Spruce Bark-beetle, *Ips borealis* Sw., and the Canadian Spruce Bark-beetle, *Ips perturbatus* Eichh., which excavate their tunnels in great numbers in all parts of the trunk, particularly in the section above the *Dendroctonus* infestation. A few weeks later other species appear, *Pissodes affinis* Rand, *Dryocoetes affaber* Mannh., *Dryocoetes americanus* Hopk., *Scierus annectens* Lec., *Crypturgus atomus* Lec., *Trypodendron bivittatum* Ky., and species of *Pityophthorus*. Of all these species, only the three first named enter the bark early enough to be of any assistance to *Dendroctonus* in overcoming the resistance of the trees.

These three species of *Polygraphus* and *Ips* enter the trees often very shortly after the attack by *Dendroctonus*, when the latter takes place early in the season, and in many cases they may be of assistance in killing the trees, since they certainly contribute towards hastening the cessation of sap flow. When only a few *Dendroctonus* attack a green tree they may be unable to check the sap-flow and so become "drowned out." These cases, apparently few, are usually connected with the second seasonal attack, and never have sustained an attack by secondaries. Probably the same *Dendroctonus* attack in the early season, supported by *Polygraphus* and *Ips* species, which would then be abundant, would succeed in killing the trees. Frequently, trees are found killed with *Dendroctonus* in the lower 8 or 10 feet and with a heavy secondary attack in the whole upper trunk.

On the other hand it is certain that a normal *Dendroctonus* attack on healthy spruce often does kill the trees without the aid of the secondary species.* Many beetle trees are found in the 2nd seasonal attack (August) in which *Polygraphus* and *Ips* do not enter the bark until the following spring, by which time the *Dendroctonus* broods are more than half grown and the needles partly fallen. It is also not uncommon to find beetle trees attacked by *Dendroctonus* on one side of the lower log only, in which the broods mature successfully and emerge the following season, but without causing the bark of the upper trunk to dry out or the needles to fall. When the bark is sufficiently green, the upper trunk is attacked early the second season by *Dendroctonus* and invariably by secondaries.

It is certain that *Dendroctonus* kills trees without the aid of the secondaries and, on the other hand, it is evident that the latter species afford sufficient help to the early season attack of *Dendroctonus* to be a factor in the development of outbreaks. This matter is referred to in the discussion of slash disposal.

Ips perturbatus Eichhoff

(The Canadian Spruce Bark-beetle)

Red to black, stout cylindric, the elytra excavated behind and armed with four teeth on each side; length, 4mm. to 5.5 mm., antennal club with arcuate sutures. Elytra with long, erect pubescence; first two elytral interspaces punctured and pubescent, 3rd and 4th impunctate; interspaces usually convex; profile of elytral suture on the disc strongly arcuate. Distinguished from *Dendroctonus* by the usually smaller size, smoother dorsal surface, and the excavated posterior extremity.

Ips perturbatus Eichh. is apparently the most important of the secondary species supporting the *Dendroctonus* outbreak in the Gaspe peninsula. It enters the trunk very shortly after the *Dendroctonus* attack commences, usually selecting the middle trunk first and later spreading downward as far as the upper portion of the *Dendroctonus* infestation. In some trees the *Ips* tunnels are scattered among those of *Dendroctonus* for a considerable distance or, particularly in fire injured trees, even throughout the base.

The tunnels of this species lie between the bark and the wood. There are usually two long egg-tunnels, from 4 to 6 inches in length, each cut by a single female, one extending upward and the other downward from a central nuptial chamber, from which an entrance tunnel extends to the exterior of the bark. The single male remains in the nuptial chamber and the entrance tunnel. In some tunnels an additional egg-tunnel is cut by a third female, directed either up or down the trunk from the chamber. Short ventilation tunnels are cut at intervals of an inch or less from the roof of the egg-tunnels into the outer bark. The eggs are placed individually, packed with boring dust, in shallow niches cut from the sides of the egg-tunnels at intervals of a centimetre or less. The larval mines are separate, rather winding at first, directed away from the egg-tunnels and eventually swinging up or down the tree, parallel with the fibres. They are about 4 to 6 inches in length when complete.

*In the Frater outbreak in 1924 several trees were found killed by the early season attack of Dendroctonus in the lower trunk without any other bark-beetle infestation.

An almost continuous emergence and attack by this species takes place throughout the summer under epidemic conditions in the Gaspe peninsula, Que. In the middle trunk of spruce killed by *Dendroctonus* or fire, matured broods of *Ips* may be found, towards the end of July, already beginning to emerge; and, above and below, tunnels in all stages of development from the condition just described to those merely started through the bark. In the summer of 1922 it appeared that there were two generations of this species or at least one and a partial second; although the matter was not definitely determined. In this species and the closely allied *Ips borealis* Sw., the parent adults of the broods which mature in the end of July apparently desert the old tunnels toward the middle of that month and start fresh tunnels in bark nearby. Towards the end of July many tunnels were seen with the broods nearing maturity and partly transformed to adults, which had been recently deserted by the parent adults; while, at the same time, many old black beetles of the same species were starting tunnels through the bark of the same or neighbouring tops and trunks.

Ips borealis Swaine

(The Lesser Northern Spruce Bark-beetle)

Usually black, slender, cylindric; 3.25 mm. to 4 mm. long; antennal club with arcuate sutures; with the declivity of the elytra excavated and armed with four teeth on each side; the front and vertex of the head convex and polished, the elytral interspaces uniseriately punctured.

Distinguished from *Dendroctonus* by its much smaller size, more slender form, smooth upper surface, polished head and excavated posterior extremity.

Ips borealis Sw. has habits very closely similar to those of *perturbatus*, but it is constantly found chiefly in the upper 25 feet or so of the top and larger branches of trees killed by *Dendroctonus* or fire, with scattered tunnels further down the trunk. This appears to be due partly to a preference which it exhibits for the thinner bark of the upper trunk, and partly to the somewhat earlier attack of its larger ally, *Ips perturbatus* Eichh.

Polygraphus rufipennis Kirby

(The Four-eyed Spruce Bark-beetle)

Stout, cylindric, black with the elytra piceous; 2 mm. long; *the eyes divided;* the antennal club unsegmented; elytra feebly striate, clothed with scales, convex behind. Distinguished from *Dendroctonus* by the very much smaller size and the characters just enumerated.

The Four-eyed Spruce Bark-beetle is excessively abundant in some of the dying spruce, while in others it is confined to the tops or, less commonly, only sparingly present. It, apparently, prefers the thinner bark of the branches and tops, though it is frequently abundant throughout the whole trunk, even on large trees. It must be ranked as second in importance to *Ips perturbatus* Eichh. in assisting in the present outbreak.

There is probably a single generation of this species in the Gaspe peninsula, Que.; but the adults have been found by the writer to leave the first tunnels of the season and apparently to cut a second set of egg-tunnels the same season.

The Effect of Fires on the Course of the Outbreak

The Gaspe outbreak was complicated by a fire which swept over part of the infested area in the early summer of 1921, between July 10 and Aug. 20. In parts of this burn the timber was very thoroughly charred and in others, particularly in heavy timber of bottom lands, the trees were burned only at the base or even on the roots. A tongue of this fire burned into the edge of

a heavily timbered spruce flat on which *Dendroctonus* had killed the greater part of the timber during the two preceding years. When we examined this area in July, 1921, the edges of the fire were still burning. Although we could find no beetle attack in the fire-injured trees at that time, a very heavy infestation of sound green trees by *Dendroctonus* was then in progress on the flat, and many of the fire-injured spruce on the burn were also attacked by *Dendroctonus* later in the season. In July, 1922, a careful examination of this region was made. Very few new trees were attacked in 1922 on the unburned portion of the spruce flat, although a large number of mature green trees were still available. Instead, the beetles had moved almost completely to the adjacent burn and entered every spruce thereon not too thoroughly dried. All the uncharred spruce bark on the burn, not occupied by *Dendroctonus*, was teeming with *Ips*, *Polygraphus* and *Dryocoetes*. These fire-injured trees had acted as a most effective trap and had drawn practically all the *Dendroctonus*, as well as the secondary beetles, from the green timber for a distance of at least about a mile; beyond this distance the character of the timber changed and the maximum distance over which the injured trees proved attractive was not determined.

It was evident that the conditions afforded an excellent opportunity for control, and that if the beetle-filled trees on the burn could be logged in the winter the outbreak should be checked. The timber owners accordingly concentrated their cut for the winter of 1922-23 on the burned area and removed the bulk of the beetle-infested logs in the drive of the following spring. As will be explained more fully, the *Dendroctonus* attack in the fire-killed trees was almost entirely on the lower log; only rarely was there any *Dendroctonus* in the upper part of the trunk; and there was, therefore, little danger from that species to be feared, in this case, from the tops.

In July 1923 the writer again examined this area and, although the removal of the beetle trees on the burn had not been entirely complete and the infested stumps had not been treated, very little fresh infestation could be found in the surrounding green timber. It thus appears that, for a time at least, the fire and the subsequent logging had proved an effective check on the outbreak in that section and that a small amount of control work during the next few years should prevent a recurrence of the injury. If the logging had not taken place it is possible that the fire would actually have accelerated the outbreak after the first season. The subsequent history of this and similar areas should be carefully studied.

The Beetle Infestation in Fire-injured Trees

In the rough country covered by this fire there is a heavy stand of large mature spruce on the bottom lands, lower hillsides and lower benches, with smaller spruce and hardwoods on the higher and steeper slopes and on the tops of the hills and steep ridges into which the country is cut. On the heights, steeper slopes and on many flats, this fire was exceptionally hot and burned or severely charred all the timber. These heavily burned trees are immune from any insect attack and when large enough to stand will remain good for pulpwood for some years. In the heavier timber the fire injury to the large spruce varied from a slight char on the large roots and extreme base to a distinct blackening of the trunk for a considerable part of its length. The bark is very thin on the large exposed roots of older spruce and a very light ground fire will kill the trees through its effect upon the roots and extreme base of the trunk. Almost invariably, large spruce burned only at the roots were attacked by *Dendroctonus* either in August, 1921, or in June and July, 1922. There were very few cases in which *Ips perturbatus* Eichh. filled the lower part of the trunk and had evidently attacked and monopolized that section of the bark before *Dendroctonus* appeared. These exceptions were so few that it could be accepted as a rule that large spruce on the burn, charred only at the roots or not higher than 2 or 3 feet up the trunk were important beetle trees; that is to say, they contained large numbers o

Dendroctonus. Very few of these fire-injured trees throw pitch tubes so that the differentiation of injury by *Dendroctonus* from that made by *Ips* can be determined only through removal of the bark or by a careful examination of the extruded boring dust lodged in the bark crevices.

Trees on which the fire had charred the bark on the lower six feet only had frequently a few *Dendroctonus* tunnels above the charred portion, in cases where *Ips* had not entered too quickly; but more often contained only *Ips*, *Polygraphus* and *Dryocoetes*, and could in all cases safely be disregarded from the standpoint of *Dendroctonus* control. A sharper burn, charring the bark far up the trunk, had left the bark dry and loose even above the char and immune from any bark-beetle attack, except for *Polygraphus* and *Dryocoetes* in the extreme top.

Even charred bark, when tight, was acceptable to *Scierus annectens* Lec. and its tunnels were found lower down on the burned trunks than those of any other species. *Scierus* does not appear to be of any economic importance.

The following descriptions are typical of the injured spruce on the burn:—

Examined, July, 1922; a white spruce, d.b.h., 18″, age 160 years; burned at roots only; foliage nearly all fallen; inner bark still moist. It had numerous *Dendroctonus* tunnels in the lower 10 feet of the trunk, 2″ to 4″ long containing eggs and young larvae. *Polygraphus*, *Dryocoetes*, *Scierus* and *Trypodendron* were entering between the *Dendroctonus* tunnels at the base, *Scierus* often starting its tunnels from the side of a *Dendroctonus* egg-tunnel. The bark of the upper part of the trunk was filled with *Ips perturbatus* Eichh. and *Ips borealis* Sw., the latter extending higher into the top; the broods of both species were nearing maturity, with large larvae and many pupae.

Examined July 11, 1922; a white spruce, d.b.h. 20 in., age 150 years; burned on roots only, standing at edge of fire, with 213 fresh *Dendroctonus* tunnels in the lower 15 feet of the trunk, varying in length up to 4 1-2 inches, with 2 or 3 egg-layers containing 30-40 eggs each, with older eggs hatched and larvae working one inch from the egg-tunnels. As usual, *Scierus* tunnels were present in the lower trunk as a secondary attack, and in the upper trunk, above the portion occupied by *Dendroctonus* and *Scierus*, the bark was filled with broods of *Ips perturbatus* Eichh., *Ips borealis* Sw., *Polygraphus*, *Dryocoetes affaber* Mannh., and *Crypturgus atomus* Lec. In a five foot section of the trunk beginning 15 feet from the ground, there were counted 204 tunnels of *Ips perturbatus* Eichh., with an average of 36 eggs in each, and 158 tunnels of *Dryocoetes affaber* Mannh. *Polygraphus rufipennis* Ky. was commencing tunnels in the limbs, preferring them to the trunk even of the extreme top; although the latter would probably be entered later by *Polygraphus*, if any room were left by *Ips borealis* Sw.

Examined July 17, 1922; a white spruce, d.b.h., 20″ extreme base of trunk scorched. *Dendroctonus* tunnels extended only four feet from the ground. Above this, *Ips perturbatus* Eichh. tunnels extended to within 25 feet of the top, a distance of about 55 feet. In the lower part of this section the tunnels were only one inch or less in length, while between 40 and 50 feet from the ground they were 3 inches long, the middle top having been attacked first by this species. *Ips borealis* Sw. was then entering the upper 25 feet of the trunk into the extreme top.

The Number of Beetles in a Single Tree

Doctor Hopkins has estimated that an average infested tree bred about 6,000 beetles of this species to maturity. Our observations lead to approximately the same estimate. The average beetle trees in the Gaspe outbreak contained about 350 *Dendroctonus* tunnels. Counts of matured broods made from selected, somewhat isolated tunnels gave an average of about 30 matured adults per tunnel. But the keener competition of the average crowded beetle

tree, in which the *Dendroctonus* larvae must contend vigorously with each other as well as with *Ips* and *Monochamus* larvae for food, would reduce this number very greatly, probably at least one-half; so that 5,000 would probably be a liberal estimate for the number of *Dendroctonus* beetles which emerge from an average infested tree. On the other hand a very heavily infested trunk, with more than 800 tunnels in the bark, might produce more than 40,000 young beetles and, although through overcrowding the number would probably be reduced to much less than half, it is evident that one large beetle-killed spruce might under favourable conditions breed beetles enough to kill from five to more than twenty healthy trees. In our *Dendroctonus* studies in British Columbia in which entire infested yellow pines have been caged and all emerging beetles captured and counted, an 18″ pine bred 4183, a 24″ tree bred 6393, and a 32″ tree, 6970 *Dendroctonus* adults, in addition to an enormous number of secondary beetles.

It is certain that in the crowded condition of a very heavy infestation, 600 to 1000 tunnels in a 24″ tree, the mortality of the larvae through lack of sufficient food material is very great, and the tendency for a swarm of beetles to overcrowd the brood trees is evidently a factor in reducing the intensity of an outbreak.

The General Attack on the Tree

Under ordinary conditions of endemic infestation the Destructive Spruce Bark-beetle breeds in dying trees injured by fire, wind break, or any cause, and in stumps and logs left from cuttings and also in healthy trees. Bark in a slightly weakened condition is undoubtedly preferred by it. Many instances could be cited. On the Saskatchewan river in northern Manitoba in August, 1922, the writer examined an outbreak of *D. piceaperda* Hopk. which, although it had spread rapidly in green timber during the previous season, could be found in very few green trees at the time of the examination. Five million feet of spruce had been cut in the winter of 1921-22 in the immediate neighbourhood of the infestation, and when examined in August the stumps, broken trunks and cull logs in the slashing contained great numbers of *Dendroctonus* broods with new tunnels still being commenced. The stumps and trunks in the slash had evidently drawn most of the beetles away from the green trees. It was evident that these broods would return to the green timber in 1923 unless very extensive cutting were continued.

The dying bark of fire-injured timber has a very strong attraction for *D. piceaperda*, sufficient, in the instance cited on page 11, to draw away practically all the beetles from a very vigorous outbreak in green timber.

Stumps of the previous winter's cut are favourite breeding places. Windfalls, culled or neglected logs and tops above 6″ in diameter are readily attacked, frequently on the underside only with the exception of the large logs. It is usual to find *Dendroctonus* on the under side, *Dryocoetes affaber* Mannh. in a band along each side, and *Ips perturbatus* Eichh. and *Ips borealis* Sw. on the top side, with *Polygraphus* usurping all available space on some trees, irregularly scattered over others, and in some limited in distribution almost solely to the tops and branches.

Extensive windfalls appear to have been the most important factor in the development of the outbreaks we have studied in recent years.

Freshly cut or broken wood appears to attract the emerging broods of this species for a considerable distance. It is a matter of common observation that blazed spruce trees along trails in the infested region are almost invariably attacked promptly by *Dendroctonus piceaperda* Hopk. and several special instances illustrating this habit have been examined by us during the last two seasons. When the Destructive Spruce Bark-beetle is abundant, trees other than spruce should be selected for blazing and as little fresh spruce wood as possible should be exposed, except on trees to be employed as traps, (page 18).

Green and rapidly growing trees of the largest size are readily attacked when there is not a sufficient amount of dying bark in the right condition available for their needs. Although the beetles will desert the green timber for fire-killed trees and slashings under certain conditions, their outbreaks have occurred in the past mostly in old mature timber, usually far from cutting operations, and have frequently continued to spread rapidly in the green trees until half or much more than half of the largest timber was killed.

The largest and oldest trees are usually preferred. It is not usual for this beetle to attack green trees much smaller than 12″ d.b.h.[1] As Hopkins has pointed out, they prefer the base of the trunk, a few feet from the ground, indicated by their earliest attack at that part. It appears probable that this preference is explained by a selection of the thickest bark, and it is also possible that the mature trees offer less resistance, in resin flow, to the beetle attack. The over mature, slowly growing trees are undoubtedly preferred; but, during an outbreak, trees making normal growth are attacked with almost equal readiness and even those growing rapidly are killed in considerable numbers. An examination of 60 trees which had been killed in a recent outbreak showed that 7 had been making rapid growth,—more than 1 cm. in the last five years, 33 had been making the normal growth for that region,—between .5 and 1 cm. in five years, and 20 had been growing slowly, less than .5 cm. in the previous five years.

Natural Control

The outbreaks are finally checked by natural control factors which are not yet well understood. Parasites have not yet played an important part in the cases studied by us, the mortality from this cause not being higher than 3 per cent. Predators, particularly the clerid beetles, have not been noticeably abundant, as they have been in the bark-beetle outbreaks in British Columbia. Woodpeckers are usually abundant and in the thin bark of the spruce their work is often apparently effective in destroying about fifty per cent of the broods in many trees. The keen competition in the brood trees, between the *Dendroctonus* larvae, themselves exceedingly overcrowded, and myriads of *Ips*, *Polygraphus*, *Dryocoetes*, *Pissodes*, *Monochamus*, and other species, must be one of the most important factors in holding outbreaks in check.

While the infestation may be held in check or reduced in severity by natural control factors, the history of these outbreaks in the past has been that often a very large amount of the most valuable timber was killed by them, frequently approximating 50% or more, before any natural control became effective. That is to say that, unless active control measures are undertaken by the forester, it can be expected that more than one-half of the finest spruce in the neighbourhood of an established outbreak will be killed. Outbreaks may last for years without increasing in severity, although killing on the whole a large amount of timber. In addition, there is the constant danger that a neglected infestation may spread with extreme rapidity and kill a whole valley of timber in a very few years.

Artificial Control of Outbreaks

If a small infestation is not increasing, that is to say, if only a few trees are killed by it each year, or if an infestation is decreasing rapidly, as indicated by a sharp reduction from the previous year in the number of fresh trees attacked, it may be sufficient to examine the situation each year and to commence control measures only when the outbreak begins to increase rapidly and to threaten valuable timber. It should be realised, however, that even the small infestations kill some timber each year and are, moreover, a source of real danger. With the safety of a large quantity of fine spruce at stake, direct control measures should be adopted at once in each valley where much valuable timber is actually

[1] In an infestation in the Algoma district of Ontario, discovered since this account was written, many trees as small as 8″, d. b. h., have been killed.

threatened by the spread of an infestation. The large, beetle-killed spruce remain valuable for pulpwood for several years after their death; but, if to be used for lumber, the beetle trees, like fire-killed trees, must be cut and utilized the first winter following their death, in order to avoid almost total loss from injury by wood borers (*Monochamus*)*.

The winter logging should be regulated, whenever this is feasible, to include any beetle infested timber in the neighbourhood, and all infested logs should be removed from the woods or placed in water in the early spring. If logging is in operation nearby so that the infested timber can be salvaged, there need be little extra expense involved in controlling a small outbreak, even though some direct control work may need to be undertaken.

Control Operations

The control consists in cutting and treating the fresh beetle trees during winter so that the broods of beetles in the bark will be killed and the spread of the outbreak checked. During the winter the broods of the destructive species will be found in the form of young adults and grubs which have not matured, beneath the bark of the trees in which they have been breeding during the summer, and in the bark of fresh windfalls, stumps and culled and neglected logs from cuttings. It is on this habit of the species that the control work is based.

It is evident that if all the infested bark in a valley could be destroyed by fire or put into water or treated in any other way so that all the contained broods would be killed, there would be no beetles left in the valley to infest green timber in the following year. It is found to be unnecessary in practice, however, to destroy all the broods, since the beetles usually prefer dying bark, and if even 75% of the broods are killed in a control operation the remaining beetles will select first the dying trees, such as windfalls, in the neighbourhood and only a few green trees will be attacked in the following season. The second year's control work on a very much smaller scale, if the first season's work has been satisfactory, should result in almost completely controlling the infestation. Thereafter it is only necessary to examine the valley each season for a few years so that further control can be undertaken if the beetles begin again to increase.

Direct Control Methods

These consist in cutting the infested trees and either peeling or burning them or putting the infested logs in water and burning the slash before the following May. Under the climatic conditions of eastern Quebec, the Maritime Provinces and Newfoundland, control work could be continued safely until the first of June.

If the infested section can be logged at once it is only necessary to take special care during the regular logging operations to cut out all the fresh beetle trees that can be found and to have them placed in water or peeled and the bark burnt before the following May. If the infested section can be logged within the ensuing two or three years the control work detailed hereafter can be conducted so as to save as many logs as possible either by peeling or placing them in water. If the timber cannot be salvaged at once and direct control work is necessary, the following plan should be adopted.

The infested section should be cruised carefully and the infested trees marked for cutting. This inspection should be made by a forest entomologist or by a competent man who has had sufficient instruction from the entomologist to be able to distinguish the trees containing the broods of the destructive species. Dead trees from which previous broods have emerged need not be

*There are a few localities along the Atlantic coast and the Gulf of St. Lawrence where these borers appear to be rare.

considered in control since the beetles never re-enter dead trees. An effort should be made to mark every fresh beetle tree; since, no matter how carefully the work is done, some will be overlooked, and the success of the operation depends upon its thoroughness.

The marked beetle trees should be felled as low as possible and the tops and branches cut and piled over the stump for burning. The trunk should be placed in water, or peeled on the infested part, or sawed into short pieces and piled over the brush and the whole burned. If water is available the logs will, of course, be placed in water in early spring and in all cases the slash should be burned.

During the latter part of the summer and in autumn before it is safe to burn, the infested bark can be removed rapidly with a narrow spade, such as those used in fire fighting. Peeling in the spring is useless since a large number of the adult beetles will survive. This method may be employed in autumn in an emergency, in order to lengthen the control period; but it has proved quicker and cheaper to saw up the tree and burn it whenever the fire hazard permits. Burning also destroys the secondary beetles (page 9) which undoubtedly play an important part in the outbreaks. If the trunk is peeled, it may be salvaged for pulp several years after it becomes infested and for lumber, if wood-boring beetles have not already entered it.

In our control operations for the yellow pine beetles in British Columbia, it is found sufficient to saw off and trim the top, remove the bark from the infested lower trunk, pile the top, branches and loose bark about the trunk and stump and fire the whole. With smaller and thin barked trees it is found cheaper and more effective to saw the tree into short lengths and pile the whole over the butt log and stump and burn. With the thinner barked eastern spruce it has been found advisable to follow the latter method, particularly since the conditions of burning, often in deep snow, render it difficult to make a long pile burn sufficiently well to destroy the bark all around the trunk. If it is found to be feasible to saw the infested trunk into logs, pile them together and obtain a successful burn, so that all the beetles and grubs are killed, the charred logs would remain salvageable, at least for pulpwood, for a number of years.

Selecting the Beetle Trees

The fresh beetle trees are distinguished by the appearance of reddish boring dust and pitch tubes on the bark, the fading colour and dropping of the foliage, the reddish appearance of the twigs after the needles have dropped and by the woodpecker work on many trees. The first indication of injury is the red boring dust dropping from the entrance holes made by the beetles and lodging in the bark scales.

The fading and dropping foliage during late summer and fall is a well-marked characteristic of infested trees and, during winter, when most of the needles have fallen from the trees attacked in June and July they are distinguished from beetle-trees of the previous year by the fresh and reddish appearance of the twigs. Trees attacked late in the season may retain considerable foliage during winter but the paler yellowish colour is usually noticeable.

Nearly all infested trees show numerous pitch tubes on the bark and may often be distinguished most readily by this means. Woodpeckers feed upon the beetles and their grubs and in the process remove a large part of the bark from the lower, infested portion of the trunk. In a careful examination of woodpecker trees in the Gaspe, Que., outbreak it was found that even in very badly riddled sections of the bark nearly half the broods had escaped. However, fresh woodpecker work on the trunk is conspicuous and often an effective aid in selecting the trees for cutting. The certain and final test of infestation is to remove some of the bark from the lower trunk with an axe; if the tree is infested the inner bark will be filled with the tunnels and living adults and grubs of the destructive species.

Trap Trees in Control

In European forests trap trees have long formed a part of bark-beetle control measures. Selected trees, often those of poor quality, are girdled or felled early in the season to attract the beetles away from the most valuable standing timber. Later, the infested trap trees are removed from the woods or treated so as to destroy the broods in the bark before the beetles emerge, and the infestation is thereby reduced.

Trap trees should prove a helpful aid to control in any managed forest; but under the present conditions in our mature spruce woods where these outbreaks chiefly occur, usually far removed from settlements, this method will probably have only a limited usefulness. It will rarely be feasible to outfit special crews for making the trap trees. Trees felled in winter or early spring and left untrimmed attract the egg-laying beetles effectively, and the following method should be valuable in some sections. Select and fell large trap-trees in winter or early spring before the men leave the woods; the trunks should become heavily infested with beetles during the summer. Make into logs, together with all fresh beetle trees in the area, in the following winter and ensure that these infested logs are removed from the woods or placed in water early in the spring.

If it could be done without excessive expense it might be well to fell additional trap trees early in July to attract the broods in the second seasonal attack.

Causes of Outbreaks

The most important factor in the development of outbreaks of the Destructive Spruce Bark-beetle is the production of large bodies of weakened or dying bark, such as slash and extensive windfalls. Neglected slash is undoubtedly the direct cause of many outbreaks of this species. Numerous specific examples of the spread of this species and its close ally, *Dendroctonus borealis* Hopk., from neglected slash to green timber, resulting in the development of vigorous local outbreaks, have been observed during recent years by the writer. While only a few of these have developed into extensive, epidemic outbreaks, several have killed a large amount of very fine timber before they subsided, and in more than one instance very extensive and destructive epidemics have been traceable apparently to the cessation of an extensive cutting. Very often the outbreaks which develop from a small body of slash last only for one or two years and then subside. Several factors may at different times be responsible for this decrease in the infestations, overcrowding, woodpeckers and insect predators being probably the most important. There is some evidence that broods in living trees originated by adults bred from dying bark suffer a high mortality, and it is often several years before the spread from slash and windfalls into green timber becomes noticeable.

There is the further question that the importance of the secondary beetles in assisting in the *Dendroctonus* outbreak makes it desirable to destroy the tops and branches of the slash in which these secondaries breed in such enormous numbers. If these secondaries could be eliminated there is little doubt that the Destructive Spruce Bark-beetle outbreaks would develop much more slowly. The writer has on several occasions found large bodies of white and black spruce dying, so well as he could determine, from an attack of *Polygraphus rufipennis* Ky., which had spread from extensive cuttings in the neighbourhood.

The whole question of the importance of slash disposal in relation to insect injury requires further careful investigation. There are, of course, conditions under which the destruction of the slash could have little effect on insect control; but, on the other hand, the writer has met with so many others in which the destruction of the slash appears to be of very great importance, that it would appear to be unwise to minimize its usefulness.

When *Dendroctonus piceaperda* Hopk. is breeding in the neighbourhood of mature spruce timber of more than 10″, d.b.h., the spruce slash from cuttings should be piled about the stumps and burned within a year from the time the trees are cut. Neglect of this matter will, in the writer's opinion, unquestionably endanger the mature spruce nearby.

Windfalls make the choicest breeding material and are usually filled with bark and wood-boring species. It is probable that the heavy windfalls and snow breaks reported in the Gaspe peninsula, Que., during recent years have been the direct cause of the bark-beetle trouble existing there now. Windfalls attacked by *Dendroctonus* in the vicinity of valuable spruce timber should be treated, that is, burned, barked or logged and put into the water, the winter or spring following their death. Whenever wood boring beetles are abundant windfalls must be salvaged the first winter or they will become almost useless for lumber.

Fires probably have an important influence upon outbreaks when they occur in a locality during the course of an infestation. It is conceivable that a fire might sweep through an infested area and, by destroying the greater part of the freshly infested trees, effectively check the epidemic. On the other hand we know that a large burn, under certain conditions, will attract to itself the greater part of the broods in a surrounding infested area, and may become an important factor in increasing the infestation in the following year; or, if the majority of the large spruce are burned on the lower 6 to 10 feet of the trunk, the broods of *Dendroctonus* commenced in the upper, unburned part of the trunk may be killed in large part through the rapid drying of the bark, so that the numbers of *Dendroctonus* beetles in the neighbourhood may thus be very effectually reduced.

PLATE I

The Destructive Spruce Bark-Beetle.

Adult beetle enlarged; actual length $\frac{1}{4}$ inch. (Swaine and Craighead).

Dendroctonus piceaperda Hopk. Adult beetle. X20.

PLATE II

The Destructive Spruce Bark-Beetle.

The tunnels as shown on the inner face of spruce bark, and the life stages of the insect. A dead male is shown embedded in a plug of hardened frass near the entrance hole. Egg L., location of egg-layer; Egg T., egg-tunnel; Ent. T., entrance-tunnel; Ent. T.2, a ventilation tunnel employed as an entrance tunnel; P.C., pupal cell; L. M., larval mines; V. T., ventilation tunnel. (Original).

PLATE II

L.M.
L.M.
L.M.
L.M.
L.M.
P.C.
ENT.T.
ENT.T.2
V.T.
EGG T.
EGG L.
L.M.
E.M.
3
4 ADULT BEETLE
2 PUPA
1 LARVA

PLATE III

The Destructive Spruce Bark-Beetle.

Tunnels on inner face of spruce bark; larvae partly grown. X ½. (Swaine and Craighead).

PLATE IV

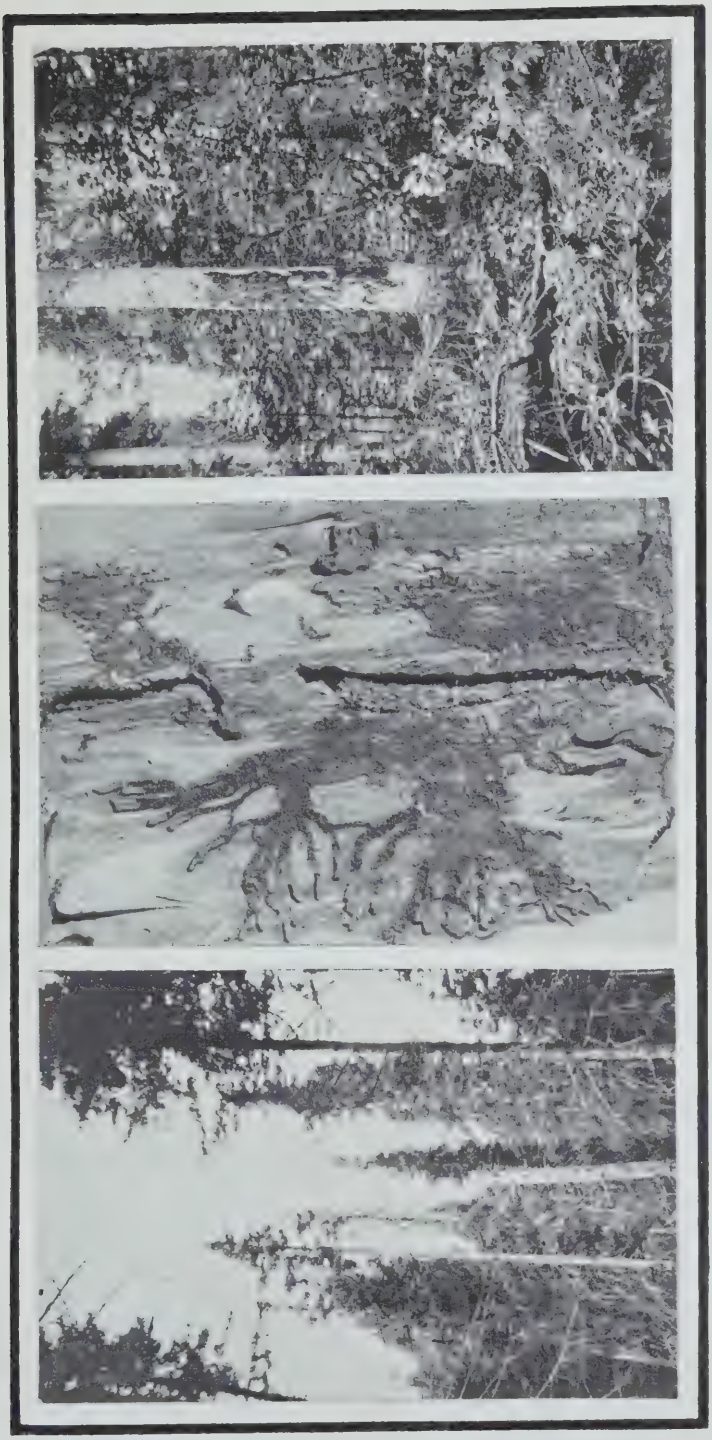
The Destructive Spruce Bark-Beetle.

Pitch Tubes shown on the bark of a white spruce trunk. (Original).

PLATE V

The Destructive Spruce Bark-Beetle

FIGURE 1. Timber killed by the spruce bark-beetle.
FIGURE 2. Tunnels in white spruce bark.
FIGURE 3. Woodpecker work on the trunk of a beetle tree. (Original).



3

2

1

PLATE VI

Secondary Bark-Beetles.

FIGURE 1. *Polygraphus rufipennis* Ky. X 25.

FIGURE 2. *Dryocoetes affaber* Mannh. X 35.

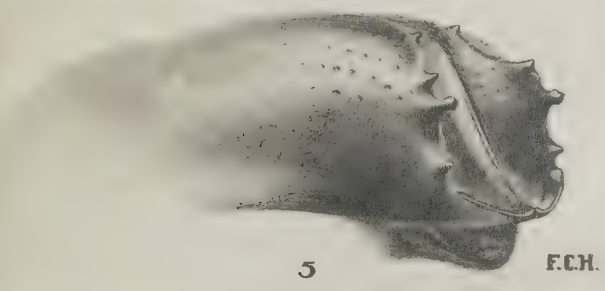
FIGURE 3. *Ips borealis* Sw. X 16.

FIGURE 4. *Ips perturbatus* Eichh.

FIGURE 5. *Ips perturbatus* Eichh. X 15. (Swaine and Craighead).

1

2



5

F.C.H.

FIG. 1.—*Polygraphus rufipennis* Ky. (After Swaine). X25.

FIG. 2.—*Dryocoetes affaber* Mannh. (After Swaine). X35.

FIG. 3.—*Ips borealis* Sw. X18.

FIG. 4.—*Ips perturbatus* Eichh., X15.

FIG. 5.—*Ips perturbatus* Eichh., showing teeth of elytral declivity

3

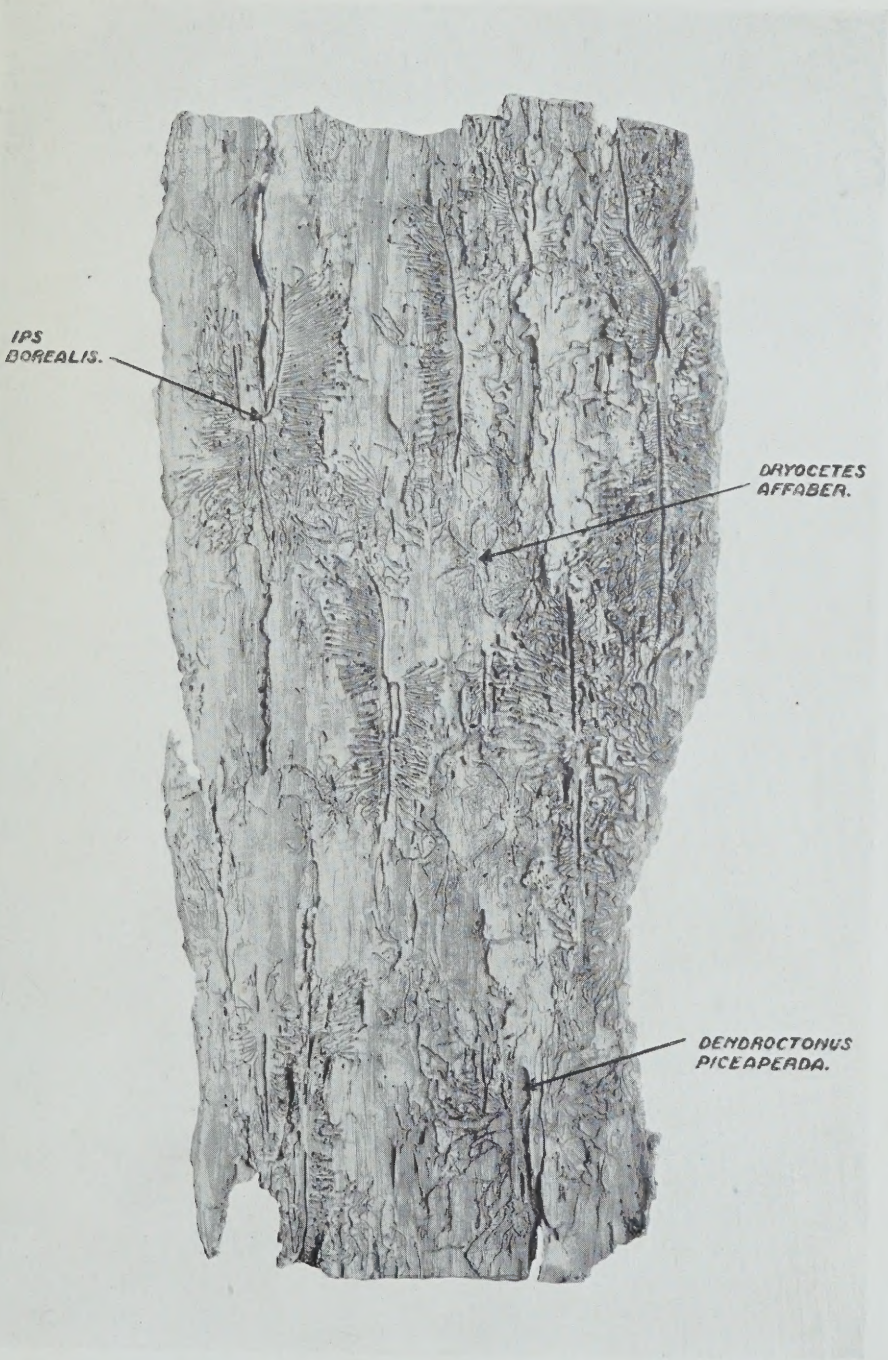
F.C.H.

4

F.C.H.

PLATE VII

Tunnels of *Ips borealis* Sw. and *Dryocoetes affaber* Mannh. on inner face of white spruce bark. X ½. (Swaine and Craighead).


IPS
BOREALIS.
DRYOCETES
AFFABER.
DENDROCTONUS
PICEAPERDA.